The Effects of Varying Concentrations of Magnesium Chloride and Sodium Chloride on Concrete

May 25, 2016

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**Abstract**

The majority of states use Sodium Chloride (NaCl) for snow and ice control, however, Magnesium Chloride (MgCl2) has increased in popularity over the past years. The primary objective of this experiment was to determine which compound, NaCl or MgCl2, would have the larger negative effect on the durability of the of concrete samples. Past studies suggest that the chloride ions in the chemicals attack the structural integrity of the concrete. Corrosion is a direct result of this interaction between the chloride ions and the concrete. In the experiment, the first step was to create aqueous solutions which break the solvents apart into their ions. This allows the ions to react with the concrete more directly. The solutions had various concentrations which allowed the different and ranging effects that NaCl and MgCl2 had on the concrete samples and the environment to be seen. The masses of the concrete were used to determine if the compound caused deterioration of the concrete and to what extent. The results of the experiment, for NaCl, were that the masses of the concrete samples overall increased. The results of the experiment, for MgCl2, were that the masses for many of the concrete samples remained remarkably close to their original masses. Those that did not remain almost the same, decreased in mass, however, not in substantial amounts. Based on these results, one major conclusion of this experiment is that MgCl2 has a greater negative effect on concrete than does NaCl. This is evident because of the decrease in masses of the concrete samples for MgCl2.

**Introduction**

Concrete is formed by the mixture of air, cement, crushed stone, sand, and water and is used to create highways, bridges, foundation, and other structures. Chloride ions are known to damage the structure of concrete, therefore weakening its durability. During snow and ice storms, countries frequently use salt to melt the snow and ice or to prevent freezing, ultimately, making it safer to drive. However, the salt is causing corrosion, weakening or even destroying structures formed to sustain massive weight. The experiment is based on this problem, “What is the most effective substance for minimizing the negative impact of snow and ice on roads. Your solution should also include a way to reduce the environmental and corrosion impacts using salt solutions?” In the experiment, the primary focus was on Magnesium Chloride and Sodium Chloride because the majority of states in North America use either of these salts. The article, Relative Effects of Sodium Chloride and Magnesium Chloride on Reinforced Concrete states, “Research has shown that the three chloride-based snow- and ice- control chemicals (NaCl, MgCl2, and CaCl2) can cause varying degrees of damage to concrete, mainly as a result of specific chemical reactions between the respective cations (Na+, Mg2+, Ca2+) with various phases of the cement paste.” (Mussato et al., 2004) Other research also supported, NaCl has shown no major effects on concrete such as deterioration. However, research has been done showing that MgCl2 has caused deterioration of concrete and to what extent is still inconclusive.

        In our experiment, we decided to vary the concentrations of each Sodium Chloride and Magnesium Chloride solutions. Based on the level of saturation for each chemical, we were able to find unsaturated and super-saturated concentrations. Varying the concentrations of each chemical allows us to determine the extent at which the chemical effects the concrete. We hypothesized that the different concentrations would cause more or less deterioration depending on the concentration. If the concentration of the solution was super-saturated, we wanted to see more deterioration than an unsaturated solution of the same chemical. We varied the concentrations because it would allow us to determine if each chemical only caused deterioration to concrete at a certain concentration. Our hypothesis was that MgCl2 would cause more deterioration to the concrete.  We based our hypothesis from the conclusions on the article, Relative Effects of Sodium Chloride and Magnesium Chloride on Reinforced Concrete.

There were four different procedures used to complete this experiment. The first procedure was for creating the concrete sample mold. The next procedure was for making the concrete. The first step was to measure the correct masses of cement, 496.75 g, and sand, 174.187 g, using an analytical balance. Then the ingredients were mixed together, using a wooden paint stick, in a mixing bowl for 1 minutes until they were completely mixed together. Next, a graduated cylinder was used to measure 150mL of distilled water. The mixture was stirred vigorously for 3 minutes with a wooden paint stick. This procedure was completed twice in order to have enough concrete sample molds to complete the experiment. After creating the molds of concrete and allowed them to complete dry, then the third procedure began. The solutions were made in the fourth procedure. Each solution either was unsaturated, saturated, or super-saturated and the concentrations of each solution was also varied. After the initial trials, the cups were modified to prevent evaporation. Throughout the following few weeks, data was collected by taking the mass of each test using an analytical balance and recorded the results in multiple data tables. After collecting data at least three times, the experiment was finished and were able to draw some conclusions.

        There were a few variables in the experiment that were manipulated and that were controlled. The independent variables, the variables that were controlled throughout the experiment, were the substance, NaCl or MgCl2, and the concentration of each substance, specifically unsaturated, saturated or super-saturated. The dependent variable, which was changing due to the independent variables, was the physical appearance of the concrete. Two variables that were controlled throughout the experiment were the time the concrete was submerged in the solution and amount of each substance used.

**Methods**

There were four different procedures used to complete this experiment. The first procedure was for creating the concrete sample mold. The next procedure was for making the concrete. The first step was to measure the correct masses of cement, 496.75 g, and sand, 174.187 g, using an analytical balance. Then the ingredients were mixed together, using a wooden paint stick, in a mixing bowl for 1 minutes until they were completely mixed together. Next, a graduated cylinder was used to measure 150 mL of distilled water. The mixture was stirred vigorously for 3 minutes with a wooden paint stick. This procedure was completed twice in order to have enough concrete sample molds to complete the experiment. After creating the molds of concrete and allowed them to complete dry, then the third procedure began. The solutions were made in the fourth procedure. Each solution either was unsaturated, saturated, or super-saturated and the concentrations of each solution was also varied. After the initial trial, the cups were modified to prevent evaporation. Throughout the following few weeks, data was collected by taking the mass of each test using an analytical balance and recorded the results in multiple data tables. After collecting data at least three times, the experiment was finished and were able to draw some conclusions.

        There were a few variables in the experiment that were manipulated and that were controlled. The independent variables, the variables that were controlled throughout the experiment, were the substance, NaCl or MgCl2, and the concentration of each substance, specifically unsaturated, saturated or super-saturated. The dependent variable, which was changing due to the independent variables, was the physical appearance of the concrete. Two variables that were controlled throughout the experiment were the time the concrete was submerged in the solution and amount of each substance used.

**Results**

In this graph, it is seen that the mass of concrete with unsaturated amounts of sodium chloride jumps over the course of the three trials. The identifiable bell curve in this graph is due to the non-uniforms masses of the concrete samples initially. Another possible explanation for the jumps in data is the fact that concrete is porous, meaning the salt and water are seeping into the pores of the concrete samples.

This graphs shows that the mass of concrete with a saturated amount of sodium chloride decreases with each trial. Concrete samples with a saturated amount of sodium chloride had the most change deterioration-wise. The near-linear decrease shape of the graph is due to the non-uniform masses of the concrete samples initially.

In the graph, the mass of concrete with super-saturated amounts of sodium chloride jumps over the course of the three trials. Concrete samples with super-saturated amounts of sodium chloride decreases in the second trial and then gains back in the third trial approximately half of the mass it lost in the second trial. The wave shape of the graph overall is due to the non-uniform masses of the concrete samples initially.

This graph shows that the mass of the concrete samples with unsaturated amounts of magnesium chloride steadily decreases with each trial. The wavelike shape of the graph is due to the non-uniform masses of the concrete samples initially.

This graph shows that the mass of the concrete samples with saturated amounts of magnesium chloride decreases in the first set of 3 trials. However, in the second two sets of 3 trials, the concrete samples with saturated amounts of magnesium chloride barely changes. The dip in the shape of the graph is due to the non-uniform masses of the concrete samples initially.

This graph shows that the mass of the concrete samples with super-saturated amounts of magnesium chloride increases in the first set of 3 trials. However, in the second set of 3 trials, the concrete samples with super-saturated amounts of magnesium chloride barely changes. Lastly, in the third set of 3 trials, the concrete samples with super-saturated amounts of magnesium chloride increases slightly less than the concrete samples of the first set of 3 trials. The odd shape of the graph is due to the non-uniform masses of the concrete samples initially.

**Discussion**

Our hypothesis was proven that MgCl2 causes more deterioration than NaCl. In our experiment, there are a few observable patterns in the data. The first of these observable patterns is that in trials 1, 2, and 3 in the mass of the concrete samples, after being submerged in NaCl, increased overall. In trial 1, the masses of the concrete samples were: (NaCl US 1) 57.85 g before, 65.43 g after; (NaCl US 2) 70. 42 g before, 80.17 g after; (NaCl US 3) 57.10 g before, 64.29 g after; (NaCl S 1) 56.58 g before, 63.31 g after; (NaCl S 2) 52.33 g before, 60.49 g after; (NaCl S 3) 37.16 g before, 43.85 g after; (NaCl SS 1) 59.19 g before, 68.46 g after; (NaCl SS 2) 46.33 g before, 52.20 g after; and (NaCl SS 3) 55.18 g before, 61.15 g after. In trial 2, the masses of the concrete samples were: (NaCl US 1) 57.85 g before, 64.97 g; (NaCl US 2) 70.42 g before, 80.27 g after; (NaCl US 3) 57.10 g before, 64.44 g after; (NaCl S 1) 56.58 g before, 62.30 g after;  (NaCl S 2) 52.33 g before, 60.49 g after; (NaCl S 3) 37.16 g before, 43.26 g after; (NaCl SS 1) 59.19 g before, 68.27 g after; (NaCl SS 2) 46.33 g before, 51.27 g after; and (NaCl SS 3) 55.18 g before, 61.53 g after, respectively. In trial 3, the masses of the concrete samples were: (NaCl US 1) 57.85 g before, 65.05 g after; (NaCl US 2) 70. 42 g before, 80.16 g after; (NaCl US 3) 57.10 g before, 64.60 g after; (NaCl S 1) 56.58 g before, 62.55 g after; (NaCl S 2) 52.33 g before, 60.07 g after; (NaCl S 3) 37.16 g before, 43.12 g after; and (NaCl SS 1) 59.19 g before, 67.02 g after, also respectively. From these increases in mass, one can deduce that the NaCl did not affect the internal structure of the concrete. In other words, the NaCl caused little to no deterioration in the concrete samples.

The next of these observable patterns is that in trial 1, trial 2, and trial 3, the mass of the concrete samples, after being submerged in MgCl2, either increased or remained at a relatively similar mass. Those samples of concrete that increased in mass in trial 1 were: (MgCl2 US 2) 63.88 g before, 66.02 g after; and (MgCl2 SS 1) 61.47 g before, 63.34 g after. Those samples of concrete that remained at a relatively similar mass in trial 1 were: (MgCl2 US 1) 65.86 g before, 66.75 g after; (MgCl2 US 3) 61.28 g before, 61.51 g after; (MgCl2 S 1) 61.47 g before, 64.44 g after; (MgCl2 S 2) 55.56 g before, 55.84 g after; (MgCl2 S 3) 39.77 g before, 39.75 g after; (MgCl2 SS 2) 57.79 g before, 57.41 g after; and (MgCl2 SS 3) 51.22 g before, 51.92 g after. Similarly, those samples of concrete that increased in mass in trial 2 were: (MgCl2 US 1) 65.86 g before, 67.00 g after; (MgCl2 S 1) 61.47 g before, 65.76 g after; and (MgCl2 SS 1) 61.47 g before, 62.98 g after. Those samples of concrete that remained at a relatively similar mass in trial 2 were: (MgCl2 US 2) 63.88 g before, 64.19 g after; (MgCl2 US 3) 61.28 g before, 61.44 g after; (MgCl2 S 2) 55.56 g before, 56.17 g after; (MgCl2 S 3) 39.77 g before, 39.81 g after; (MgCl2 SS 2) 57.79 g before, 57.24 g after; and (MgCl2 SS 3) 51.22 g before, 51.91 g after. Similarly, those samples of concrete that increased in mass in trial 3 were: (MgCl2 US 1) 65.86 g before, 69.04 g after; (MgCl2 S 1) 61.47 g before, 65.86 g after; and (MgCl2 SS 1) 61.47 g before, 63.63 g after. Those samples of concrete that remained at a relatively similar mass in trial 3 were: (MgCl2 US 2) 63.88 g before, 64.02 g after; (MgCl2 US 3) 61.28 g before, 61.63 g after; (MgCl2 S 2) 55.56 g before, 55.88 g after; (MgCl2 S 3) 39.77 g before, 39.86 g after; (MgCl2 SS 2) 57.79 g before, 57.35 g after; and (MgCl2 SS 3) 51.22 g before, 51.65 g after. From the increases, one can deduce that the MgCl2 did not affect the internal structure of the concrete—similarly to trials 1, 2, and 3 of the NaCl. However, from the trivial changes in mass, such as (MgCl2 US 1), (MgCl2 US 3), (MgCl2 S 1), (MgCl2 S 2), (MgCl2 S 3), (MgCl2 SS 2), and (MgCl2 SS 3) from trial 1;  (MgCl2 US 2), (MgCl2 US 3), (MgCl2 S 2), (MgCl2 S 3), (MgCl2 SS 2), and (MgCl2 SS 3) from trial 2; and (MgCl2 US 2), (MgCl2 US 3), (MgCl2 S 2), (MgCl2 S 3), (MgCl2 SS 2), and (MgCl2 SS 3) from trial 3, one can deduce that the MgCl2 caused more deterioration in the concrete samples.

This difference is shown in the data table called, trial 1: Mass of Concrete Before and After Being Submerged in a Magnesium Chloride Solution, trial 2: Mass of Concrete Before and After Being Submerged in a Magnesium Chloride Solution, and trial 3: Mass of Concrete Before and After Being Submerged in a Magnesium Chloride Solution. The raw data shows that the masses of the concrete either increased or decreased a slight amount rather that in the data from the NaCl trials all the masses increased by a larger amount. For deterioration to be proven, the masses of the concrete must decrease after being submerged in the solutions. In our experiment, there were multiple errors that could explain why the masses of the concrete did the opposite of what we expected. These most prominent errors is the type of covering used to conceal the cups of concrete. At the beginning of the experiment the cups were not covered with plastic wrap which allowed most if not all of the solutions to evaporate. If the water evaporates, its initial presence can still have a slight lasting impact on the concrete; evaporated solution could still corrode the concrete. It is important for the solution to be present in the cup for the duration of the experiment because the solution is what affects the concrete most directly. The absences of the solutions in the cups would impact the experiment in that the concrete would, from that point on, only be affected by the remaining solution in the cup, rather than the original intended amount. Another example is that we did not allow the concrete to dry completely before taking the mass. This means that the mass increase could be due to the weight of the water absorbed by the concrete which would not allow us to see the actual effects that the solutions had on the concrete.

For further research, someone could continue doing the same experiment however eliminating the errors that we made. Covering the cups with wax paper would prevent evaporation and create more accurate data. The best thing to cover the solution with would be plastic wrap because it minimizes the exposure to air whilst keeping the solution mass relatively close to its initial amount. Rather than using plastic wrap, in our experiment, we originally used paper towels, however, it deemed itself useless, so we then switched to using wax paper. When that ran out, we used plastic wrap—this proved to be most effective. Also, most deterioration of concrete takes a few years and completing the experiment over a longer period of time with more trials would also provide more accurate and conclusive data. Ideally, a longer period would be approximately 12-36 months (1-3 years), 10 years, and 25 years. These periods would help better conclusions in the data to be drawn because according to magnesium chloride use has been reported only as far as 15 years, and 6 years extensively (Mussato et al., 2004).

In doing the experiment a second time, we would do multiple things differently. By ensuring the least amount of evaporation as possible, the data would be more accurate because the concrete would be affected by almost the original amount of solution. Secondly, we would plan ahead from the beginning in terms of when data should be taken. Someone would want to control for the amount of time the concrete should sit and for when they take data collection to make it uniform. This would allow someone to plot their data on a line graph and see the changes over time. We would schedule it so that the data was taken over the longest time period possible. By taking data over the longest time period possible, we would create a more realistic simulation of how true, exposed concrete deteriorates. Thirdly, we would measure out all of the concrete samples to have the same mass. Creating concrete samples with one, uniform mass would allow the differences in mass, in other words, the deterioration, of the samples to be seen with greater ease. Lastly, we would put rebar in our concrete samples, as this would further create a more realistic approach to explore the deterioration of concrete. Rebar is metal, cut into bars, used to increase the tensile strength of concrete. Rebar could add to the experiment because it could help prevent shifting and corrosion in the concrete.

One qualitative thing to look or test for includes strength. One could test the strength of concrete throughout the experiment by applying a weight to the concrete samples each time data is taken. In placing a weight on a concrete sample, one could measure how much force, applied by the weight, said concrete sample could withstand. If a concrete sample, well into the experiment, could only withstand significantly less weight than it could withstand before absorbing the salts from the solutions. Visible signs of corrosion one could look for include cracks and discoloration of the concrete samples. The pH of a concrete solution should be approximately 11—definitely above 7 to be acidic. Furthermore, the salts in the concrete solutions lower the pH level of the solution in which the concrete is. Because of this, one could predict which concrete solution to use for the best results—meaning, least deterioration.

One could test a solution over time for it impact on the concrete by measuring its pH each time data was collected. The solutions did, in fact, change. This change is evident due to the increasing murkiness of the solution visibly, as well as the visible dirt, such as insects, that gathered in some cups over time.

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**Appendix**

Data Tables:

Trial 1: Mass of Concrete Before and After Being Submerged in a Sodium Chloride Solution

|  |  |  |
| --- | --- | --- |
| Solution and Concentration | Mass Before Concrete submerged in solution | Mass After Concrete submerged in solution |
| NaCl US 1 | 57.85 g | 65.43 g |
| NaCl US 2 | 70. 42 g | 80.17 g |
| NaCl US 3 | 57.10 g | 64.29 g |
| NaCl S 1 | 56.58 g | 63.31 g |
| NaCl S 2 | 52.33 g | 60.49 g |
| NaCl S 3 | 37.16 g | 43.85 g |
| NaCl SS 1 | 59.19 g | 68.46 g |
| NaCl SS 2 | 46.33 g | 52.20 g |
| NaCl SS 3 | 55.18 g | 61.15 g |

Trial 2: Mass of Concrete Before and After Being Submerged in a Sodium Chloride Solution

|  |  |  |
| --- | --- | --- |
| Solution and Concentration | Mass Before Concrete submerged in solution | Mass After Concrete submerged in solution |
| NaCl US 1 | 57.85 g | 64.97 g |
| NaCl US 2 | 70.42 g | 80.27 g |
| NaCl US 3 | 57.10 g | 64.44 g |
| NaCl S 1 | 56.58 g | 62.30 g |
| NaCl S 2 | 52.33 g | 60.49 g |
| NaCl S 3 | 37.16 g | 43.26 g |
| NaCl SS 1 | 59.19 g | 68.27 g |
| NaCl SS 2 | 46.33 g | 51.27 g |
| NaCl SS 3 | 55.18 g | 61.53 g |

\*for NaCl SS 2 and 3, 40 mL of water was added in order to make an aqueous solution

Trial 3: Mass of Concrete Before and After Being Submerged in a Sodium Chloride Solution

|  |  |  |
| --- | --- | --- |
| Solution and Concentration | Mass Before Concrete submerged in solution | Mass After Concrete submerged in solution |
| NaCl US 1 | 57.85 g | 65.05 g |
| NaCl US 2 | 70. 42 g | 80.16 g |
| NaCl US 3 | 57.10 g | 64.60 g |
| NaCl S 1 | 56.58 g | 62.55 g |
| NaCl S 2 | 52.33 g | 60.07 g |
| NaCl S 3 | 37.16 g | 43.12 g |
| NaCl SS 1 | 59.19 g | 67.02 g |

\*for NaCl SS 2 and 3, 40 mL of water was added in order to make an aqueous solution

Trial 1: Mass of Concrete Before and After Being Submerged in a Magnesium Chloride Solution

|  |  |  |
| --- | --- | --- |
| Solution and Concentration | Mass Before Concrete submerged in solution | Mass After Concrete submerged in solution |
| MgCl2 US 1 | 65.86 g | 66.75 g |
| MgCl2 US 2 | 63.88 g | 66.02 g |
| MgCl2 US 3 | 61.28 g | 61.51 g |
| MgCl2 S 1 | 61.47 g | 64.44 g |
| MgCl2 S 2 | 55.56 g | 55.84 g |
| MgCl2 S 3 | 39.77 g | 39.75 g |
| MgCl2 SS 1 | 61.47 g | 63.34 g |
| MgCl2 SS 2 | 57.79 g | 57.41 g |
| MgCl2 SS 3 | 51.22 g | 51.92 g |

Trial 2: Mass of Concrete Before and After Being Submerged in a Magnesium Chloride Solution

|  |  |  |
| --- | --- | --- |
| Solution and Concentration | Mass Before Concrete submerged in solution | Mass After Concrete submerged in solution |
| MgCl2 US 1 | 65.86 g | 67.00 g |
| MgCl2 US 2 | 63.88 g | 64.19 g |
| MgCl2 US 3 | 61.28 g | 61.44 g |
| MgCl2 S 1 | 61.47 g | 65.76 g |
| MgCl2 S 2 | 55.56 g | 56.17 g |
| MgCl2 S 3 | 39.77 g | 39.81 g |
| MgCl2 SS 1 | 61.47 g | 62.98 g |
| MgCl2 SS 2 | 57.79 g | 57.24 g |
| MgCl2 SS 3 | 51.22 g | 51.91 g |

Trial 3: Mass of Concrete Before and After Being Submerged in a Magnesium Chloride Solution

|  |  |  |
| --- | --- | --- |
| Solution and Concentration | Mass Before Concrete submerged in solution | Mass After Concrete submerged in solution |
| MgCl2 US 1 | 65.86 g | 69.04 g |
| MgCl2 US 2 | 63.88 g | 64.02 g |
| MgCl2 US 3 | 61.28 g | 61.63 g |
| MgCl2 S 1 | 61.47 g | 65.86 g |
| MgCl2 S 2 | 55.56 g | 55.88 g |
| MgCl2 S 3 | 39.77 g | 39.86 g |
| MgCl2 SS 1 | 61.47 g | 63.63 g |
| MgCl2 SS 2 | 57.79 g | 57.35 g |
| MgCl2 SS 3 | 51.22 g | 51.65 g |

The negative control variable maintained a steady mass of 42.05 g throughout the entirety of the experiment.

Calculations for the concentrations of the solutions:

MgCl2 values –

Unsaturated 1 = 60g of solvent/100 mL of water

Unsaturated 2 = 50g of solvent/100 mL of water

Unsaturated 3 = 40g of solvent/100 mL of water

Saturated 1,2,3 = 70g of solvent/100 mL of water

Super-Saturated 1 = 80g of solvent/100 mL of water

Super-Saturated 2 – 90g of solvent/100 mL of water

Super-Saturated 3 – 100g of Solvent/100mL of water

NaCl values –

Unsaturated 1 = 25.7 of solvent/100 mL of water

Unsaturated 2 = 15.7g of solvent/100 mL of water

Unsaturated 3 = 5.7g of solvent/100 mL of water

Saturated 1,2,3 = 35.7g of solvent/100 mL of water

Super-Saturated 1 = 45.7g of solvent/100 mL of water

Super-Saturated 2 – 55.7g of solvent/100 mL of water

Super-Saturated 3 – 65.7g of Solvent/100mL of water

MgCl2 Solutions and Concrete:



NaCl Solutions and Concrete:



Independent variable: concentration of each substance

Dependent variable: mass of concrete after being submerged in solution

Negative control: concrete in water

Controlled variables: time concrete is submerged in solution, amount each of each solution

Materials list:

Concrete –

* Cement
* Sand
* Distilled water
* Ruler
* Sharpie
* Mixing bowl
* Wooden paint stick
* Graduated cylinder
* Paper towel
* Wax paper
* 3oz paper cup
* Scissors
* Analytical balance
* Scoopula
* Weigh boat
* Rubber band

Solutions –

* Distilled water
* Sodium chloride
* Magnesium chloride
* Sharpie
* Plastic cups
* Analytical balance
* Graduated cylinder
* Ruler
* Beaker
* Scoopula

MSDS:

* Magnesium Chloride: flush eyes with water for 15 minutes with eyes open, flush skin with lots of water and non-abrasive soap, cover affected skin with emollient
* Sodium Chloride: flush eyes with water for 15 minutes, flush skin with lots of water, cover affected skin with emollient

Procedures:

Making the Concrete Sample Mold:

1. Obtain a 3oz paper cup. Write your group name on the outside of the cup with a sharpie.
2. Measure, using a ruler, ¾ inch from the base of the cup and mark a line around the interior of the cup with a sharpie at this height.
3. Line the entire interior of the paper cup with wax paper and then fold the excess wax paper over the top of the cup and secure in place with a rubber band.
4. Use your fingertips to press the wax paper against the interior of the cup.

Making the Concrete:

1. Measure 496.75 g cement and 174.187 g sand using an analytical balance.
2. Place both materials into a mixing bowl.
3. Using the wooden paint stick, mix these dry ingredients together for 1 minute until uniform in mixture.
4. Measure 150 mL of distilled water using a graduated cylinder,
5. Slowly pour the water into the bowl with the cement and sand while mixing with the wooden paint stick.
6. Stir vigorously for 3 minutes.
7. Each batch will fill approximately 10, 3oz paper cups.

Labeling procedure:

1. Make 19 samples of concrete in Dixie cups
2. Begin labeling Dixie cup concrete samples with a sharpie: with the substance and concentration (US -- unsaturated, S -- saturated, and SS -- super-saturated) and (1, 2, 3 corresponds to the varying concentrations)
   * 1. sample 1 - negative control
     2. sample 2 - MgCl2 US1
     3. sample 3 - NaCl US1
     4. sample 4 - MgCl2 US2
     5. sample 5 - NaCl US2
     6. sample 6 - MgCl2 US3
     7. sample 7 - NaCl US3
     8. sample 8 - MgCl2 S1
     9. sample 9 - NaCl S1
     10. sample 10 - MgCl2 S2
     11. sample 11 - NaCl S2
     12. sample 12 - MgCl2 S3
     13. sample 13 - NaCl S3
     14. sample 14 - MgCl2 SS1
     15. sample 15 - NaCl SS1
     16. sample 16 - MgCl2 SS2
     17. sample 17 - NaCl SS2
     18. sample 18 - MgCl2 SS3
     19. sample 19 - NaCl SS3
3. Wait for concrete to harden
4. Remove each sample from Dixie cups and place each sample in a plastic cup
5. Measure mass of each concrete sample using an analytical balance and record in data table
6. Label the plastic cups with the same as the corresponding sample label

Solutions procedure:

1. Begin making the solutions:
   1. For sample 1 – measure 100 mL of water using a graduated cylinder
   2. For sample 2 – create solution by measuring out 60 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   3. For sample 3 – create solution by measuring out 25.70 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   4. For sample 4 – create solution by measuring out 50 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   5. For sample 5 – create solution by measuring out 15.70 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   6. For sample 6 – create solution by measuring out 40 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   7. For sample 7 – create solution by measuring out 5.7 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   8. For sample 8 – create solution by measuring out 70 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   9. For sample 9 – create solution by measuring out 35.7 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   10. For sample 10 – create solution by measuring out 70 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   11. For sample 11 – create solution by measuring out 35.7 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   12. For sample 12 – create solution by measuring out 70 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   13. For sample 13 – create solution by measuring out 35.7 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   14. For sample 14 – create solution by measuring out 80 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   15. For sample 15 – create solution by measuring out 45.7 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   16. For sample 16 – create solution by measuring out 90 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   17. For sample 17 – create solution by measuring out 55.7 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   18. For sample 18 – create solution by measuring out 100 grams of MgCl2 using an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap
   19. For sample 19 – create solution by measuring out 65.7 grams of NaClusing an analytical balance and measure out 100 mL of water using a graduated cylinder. Mix the two ingredients together in a volumetric flask. Pour solution onto concrete and cover the plastic cup with plastic wrap